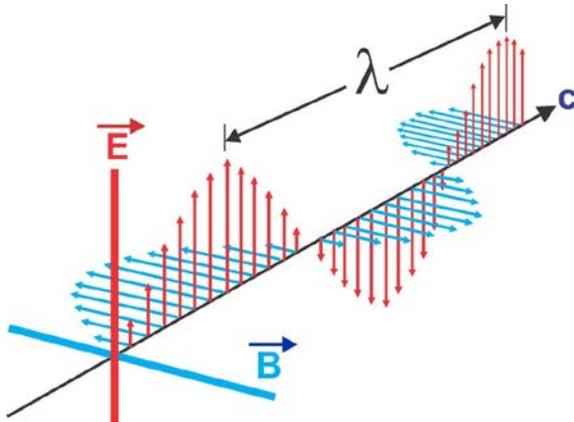


## Electromagnetic waves.

**Constant current generates a magnetic field, and oscillating electric charges generate oscillating magnetic field. (Steadily changing B induces a constant V, and oscillating magnetic field generates oscillating voltage.)**

Electric (E) and Magnetic fields (B) oscillate in time and space. Theory due to James Clerk Maxwell.



E and B directions mutually perpendicular

Travel in direction C ( $\parallel E \times B$ ) at speed of light

$$c = 3.10^8 \text{ m/s}$$

Peaks (of either E or B) occur periodically in space separated by wavelength  $\lambda$ .

Periodicity in time  $T = 1/f$

f = frequency

$$c = f\lambda$$

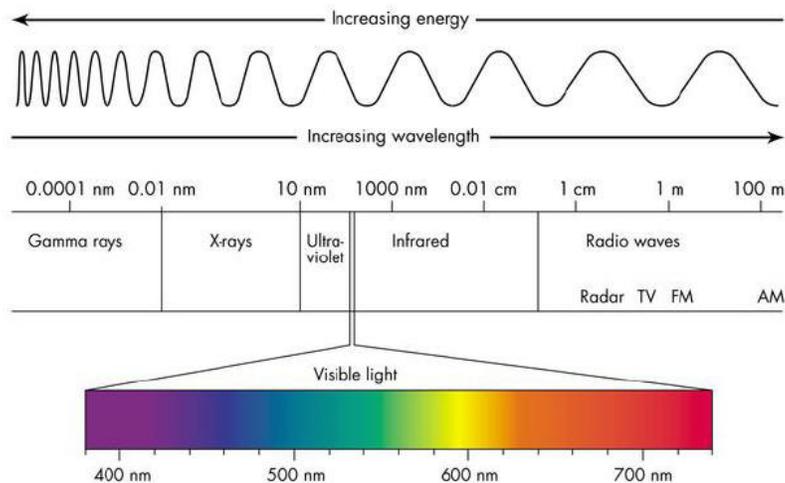
MHz radio waves,  $10^6$  Hz

GHz microwaves  $10^9$  -  $10^{11}$  Hz

Infra-red  $10^{13}$  Hz

Light  $10^{15}$  Hz

E.g. For  $3.10^9$  Hz microwaves,  $\lambda = 0.1 \text{ m} = 10 \text{ cm}$



Violet light  $\lambda = 400 \text{ nm}$  ( $10^{-9} \text{ m}$ ),  $f = 7.5 \times 10^{14} \text{ Hz}$ . Red light  $\lambda = 700 \text{ nm}$ ,  $f = 4.3 \times 10^{14} \text{ Hz}$

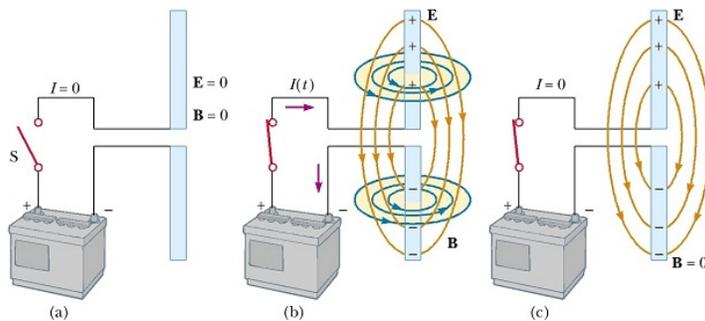
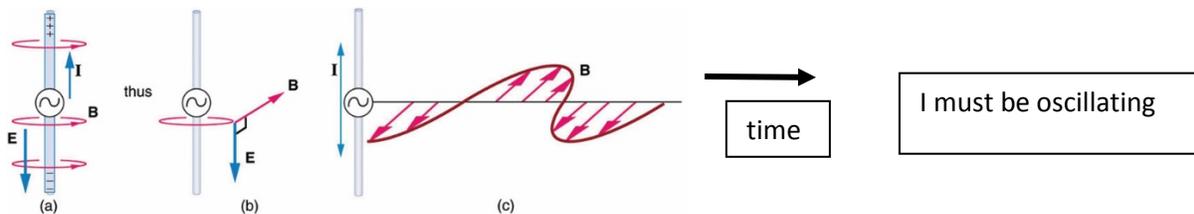
## Heinrich Hertz (1857-1894)

He received a Ph.D. magna cum laude from the [University of Berlin](#) in 1880, where he studied under [Hermann von Helmholtz](#). In 1883 he began his studies of Maxwell's electromagnetic theory. Between 1885 and 1889, while he was professor of [physics](#) at the Karlsruhe Polytechnic, he produced [electromagnetic waves](#) in the laboratory and measured their length and [velocity](#). He showed that the nature of their vibration and their susceptibility to reflection and [refraction](#) were the same as those of light and heat waves. As a result, he established beyond any doubt that light and heat are electromagnetic radiations. The electromagnetic waves were called Hertzian and, later, [radio](#) waves. (He was not the first to produce such waves. Anglo-American inventor [David Hughes](#) had done so in work that was almost universally ignored in 1879, but Hertz was the first to correctly understand their electromagnetic nature.)



Credit: Encyclopedia Britannica)

## Making EM Waves



Transient current  $I(t)$  generate a wave, but must keep  $I(t)$  oscillating to generate a continuous wave that radiates outward.